G.H. RAISONI INSTITUTE OF ENGINEERING & TECHNOLOGY, NAGPUR

(An Autonomous Institute)

Department of Electrical Engineering

Subject:- ELECTRICAL POWER SYSTEM-I
Subject Code:- NEEL 311
5th Sem EE

Presented By,
Rashmi S. Phasate
EE Department

Contents

- Introduction
- Course Outcome
- Syllabus
  - Unit 1: Generalized Structure of Electrical Power System
  - Unit 2: Representation of Power System Elements
  - Unit 3: Feeders, Distributors, Cables and Insulator
  - Unit 4: Voltage Regulation & Efficiency of Transmission Lines
  - Unit 5: Load Flow Analysis
  - Unit 6: Real and Reactive Power Control
- Text Books and Reference books
- Generalized Structure of Electrical Power System

Introduction

- Electrical power is generated, transmitted and distributed in the form of alternating current.
- The electrical power is produced at the place which are located generally quite away from the consumer.
- It is delivered to consumer through a large network of transmission and distribution at many places in the line of power system.
- It may be desirable and necessary to change some characteristics for example: Voltage level, frequency, power factor of AC supply. This is accomplished by suitable operators called Substations.

- The transmission systems supply bulk power and the distribution systems transfer electric power to the ultimate consumers.
- The generation of the electric energy is nothing but the conversion of one form energy into electrical energy.
- Electrical energy is generated in hydro, thermal and nuclear power stations.
- Sometimes, electrical energy is generated from nonrenewable energy sources like wind, waves, fossil fuels, etc. The generating voltages are usually 11kV, 33kV.

COURSE OUTCOME

After the completion of course student will be able to,

1] Study and analyze the different power system components and parameters.
2] Represent elements of a power system including generators, transmission lines, and transformers using single line diagram and analyze the whole system numerically.
3] Study construction of different feeders, distributors, insulators and cables.
4] Demonstrate an awareness of the methods used for voltage regulation in electrical power networks.
5] Apply load flow analysis to an electrical power network and interpret the results of the analysis.
6] Identify real and reactive power flow in power system and control it using different methods.

SYLLABUS

Unit 1: Generalized Structure of Electrical Power System

Structure of electrical power system, brief exposure to generation, transmission and distribution aspects, elementary consideration of economic bulk power supply system, use of high voltage general system consideration, idea about substation, concept of real, reactive and complex power. Load and their characteristics, voltage and frequency dependence of loads.

Unit 2: Representation of Power System Elements

Representation of power system elements, models and parameters of generator, transformer and transmission lines, Transmission line parameters calculation (R,L,C), per unit system representation.

SYLLABUS

Unit 3: Feeders, Distributors, Cables and Insulator

Elementary distribution scheme: Feeders and distributors. LT and HT cables, Introduction to distribution automation. Concept of insulator, types of insulator, string efficiency

Unit 4: Voltage Regulation & Efficiency of Transmission Lines

Voltage regulation and efficiency of power transmission lines using equivalent pi and T representation. Representation using circle diagram with generalized constants.

SYLLABUS

Unit 5: Load Flow Analysis

Interconnection of system elements to form two bus systems. Illustration of active and reactive power transmission, types of buses. Introduction to load flow studies in multibus system. Introduction of frequency and voltage as system state indicators.

Unit 6: Real and Reactive Power Control

Elementary concepts of real and reactive power control. Steady state performance of turbine governors, load sharing between generators, preliminary concepts of automatic voltage regulator.

Text and Reference Books

Text Books:

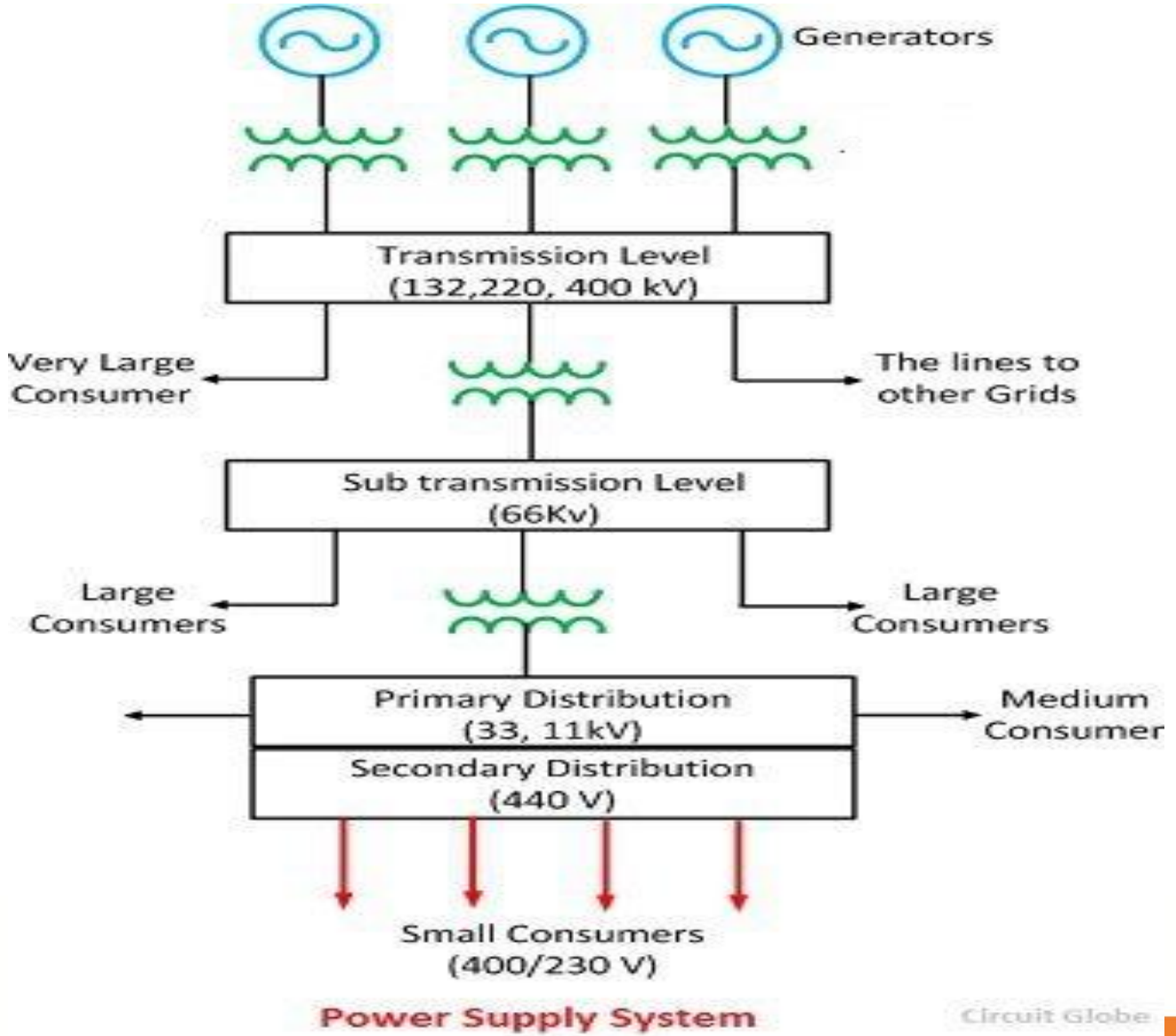
- Modern Power system analysis, Nagrath I.J. & Kothari D.P., Mc-Graw Hill
- Power system analysis, Wadhwa C.L., New-Age international
- Electrical Power System, Ashfaque Hussain, CBS

Reference Books:

- Elements of power system analysis, W. D. Stevenson, PHI
- A Text book of Electric Power Distribution, Automation Dr. M. K. Khedkar & Dr. G. M. Dhole , Laxmi Publications
- Electric Energy System Theory, O. E. Elgerd

Generalized Structure of Electrical Power System

Structure of AC Power System



Engineering | Management | Law | Schools | Other Courses
NAGPUR PUNE JALGAON AMRAVATI AHMEDNAGAR CHHINDWARA
RAISONI GROUP OF INSTITUTIONS

Components of an electric power system

- **Generators**: A device used to convert one form of energy into electrical energy.
- **Transformer:** Transfer power or energy from one circuit to other without the change of frequency.(to increase or decrease the voltage level)
- **Transmission Lines:** Transfer power from one location to another
- **Control Equipment:** Used for protection purpose
- **Primary Transmission:** 110kV, 132kV or 220kV or 400kV or 765kV, high voltage transmission, 3 phase 3-wire system.
- **Secondary Transmission**: 3 phase 3-wire system, 33kV or 66kV feeders are used
- **Primary Distribution:** 3 phase 3-wire system, 11kV or 6.6kV
- **Secondary Distribution**: 400V for 3φ, 230V for 1φ

Generators:

- Generator is a device which converts mechanical energy into electrical energy. Generating voltages are normally 6.6 kV,10.5 kV or 11 kV.

- This generating voltage can be step up to 110 kV/132 kV/220kV at the generating(indoor or outdoor) to reduce the current in transmission line and to reduce transmission losses.

- Generators produce real power (MV) and reactive power (MVAR).

Transformers:

- It is a static device which transfers power or energy from one circuit to another circuit without change of frequency.

- The main function of transformers is step up voltages from lower generation levels to the higher generation voltage levels and also step down voltages from higher transmission voltage levels to lower distribution levels.

- When we are increasing the transmission voltage, current flowing through the grid decreases, thereby transmission losses reduces.

Control Equipment

Circuit Breaker (CB): Circuit breakers are used for opening or closing a circuit in normal and abnormal (fault) condition.

- Different types of circuit breaker are oil circuit breaker, air-blast circuit breaker, vacuum circuit breaker, SF6 circuit breaker.
- During fault conditions relay will give command to the circuit breaker to operate.

Isolators: Isolators are placed in substations to isolate the part of system during maintenance.

- It can operate only during no-load condition. Isolated switches are provided on each side of the circuit breaker.

Contd…

Busbar:

- Busbars are used to connect number of lines operating at the same voltage electrically.
- It is made up of copper or aluminum.
- Different types of busbar arrangements are –single busbar arrangement, single bus bar with sectionalisation, double bus bar arrangements, ring bus bar scheme.

Transmission System

- It supplies only large blocks of power to bulk power station or very big consumers.
- It interconnects the neighbouring generating stations in to a power pool i.e, interconnection of two or more generating stations.
- Tolerance of transmission line voltage is ±5 to ± 10% due to the variation of loads.

Primary Transmission

- If the generated power is transmitted through transmission line without stepping up the generated voltage, the line current and power loss would be very high.
- So the generated voltage is stepped up to higher value by using the step up transformer located in substations known as sending end substations near the generating stations.

Contd…

- The high voltage transmission lines transmit power from sending end substation to the receiving end substation.

- Primary transmission voltages are 110KV, 132 KV or 220KV 0r 400KV or 760KV.It uses 3phase, and 3wire system.

Secondary Transmission

- At the receiving end substation, the voltage is stepped down to a value of 66 or 33 or 22 KV using step down transformers.

- The secondary transmission line forms the link between the receiving end substation and the secondary station. It uses 3phase,3 wire system and the conductors used are called feeders.

Distribution System

- The component of an electrical power system connecting all the consumers in an area to the bulk power sources or transmission line is called a distribution system.
- A distribution station distributes power to domestic, commercial and relatively small consumers.
- Distribution transformers are normally installed on poles or on plinth mounted or near the consumers Primary Distribution
- At the secondary substations, the voltage is stepped down to 11 KV or 6.6 KV using step down transformers.
- The primary distributor forms the link between secondary substation and distribution substation and the power is fed in to the primary distribution system. It uses 3phase, 3 wire system.

Secondary Distribution

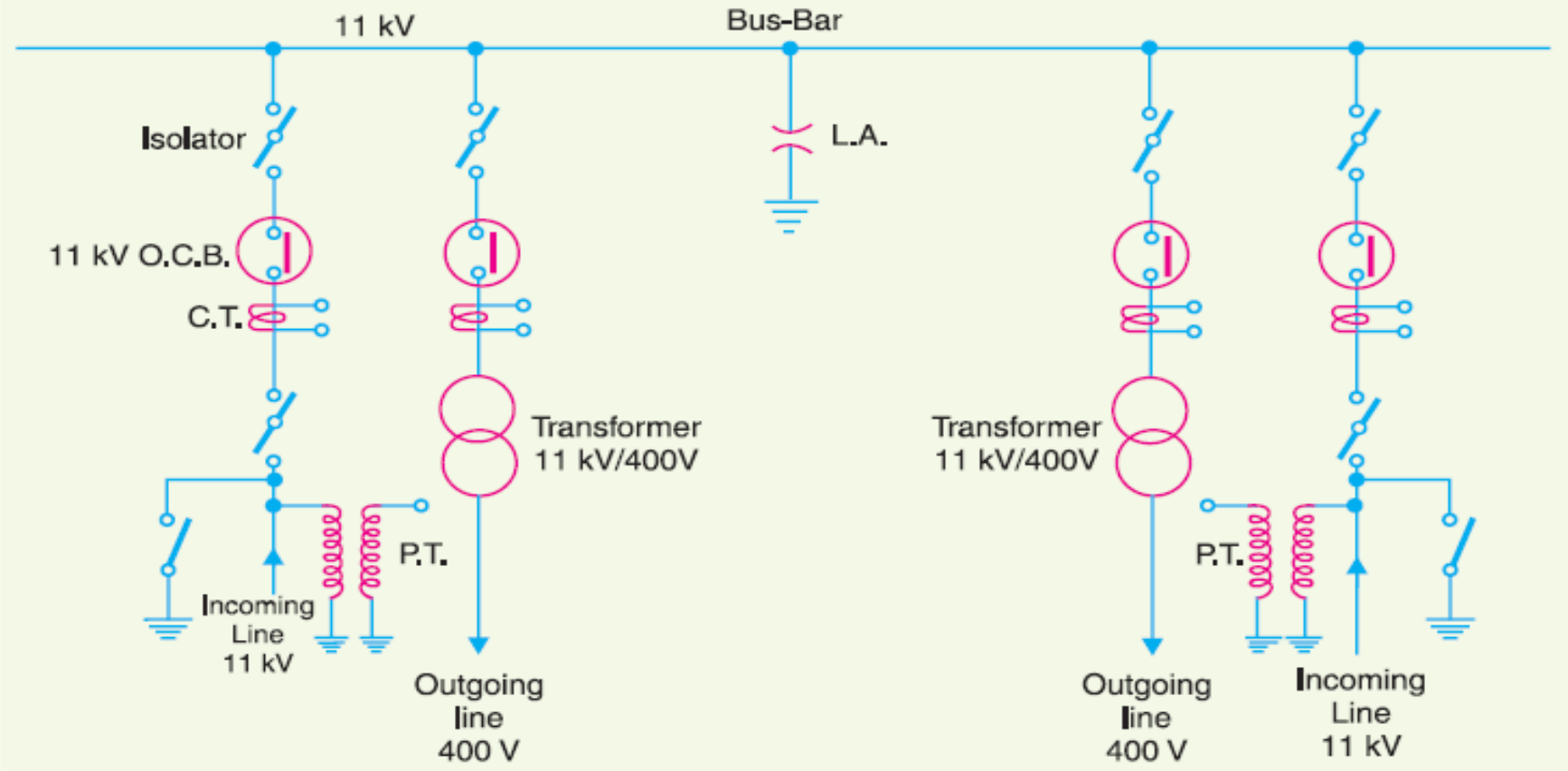
- At the distribution substation the voltage is stepped down to 400V (for 3phase) or 230V (for 1 phase) using step down transformers.

- The distribution lines are drawn along the roads and service connections to the consumers are tapped off from the distributors.

- It uses 3 phase, 4 wire system.

- Single phase loads are connected between one phase wire and one neutral wire.

Substation



Single Line Diagram of 11kV Substation

Substation

➢The Assembly of apparatus used to change some characteristic like voltage level, frequency power factor etc, of electric supply is called substation. For Example…
1] Generation voltage at 11kV at power station is stepped upto 220kV for transmission with the help of transformer. The assembly of transformer is called substation.
2] In consumer area voltage may have to be decreased for utilization. The assembly is called substation.

➢Thus equipment needed in substation depend upon service required. Hence substation is the important part of electrical.

➢ For proper functioning and countinuity of supply, substations should be properly designed.

Substation



Courtesy of http://www.osha.gov

Equipment in Substation

Transformer : Power transformers raise or lower the voltage as needed to serve the transmission or distribution circuits.

Potential transformers : Potential transformers are required to provide accurate voltages for meters used for billing industrial customers or utility companies

Current transformers : Current transformers can be used to supply information for measuring power flows and the electrical inputs for the operation of protective relays associated with the transmission and distribution circuits or for power transformers. These current transformers have the primary winding connected in series with the conductor carrying the current to be measured or controlled. The secondary winding is connected to low-voltage metering circuits.

Equipment in Substation

Rectifier: A rectifier is a device used to convert alternating current to direct current.

Frequency Changer : A frequency changer is a motor-generator set that changes power of an alternating current system from one frequency to one or more different frequencies, with or without a change in the number of phases, or in voltage.

Lightning Arresters: Lightning arresters are protective devices for limiting surge voltages due to lightning strikes or equipment faults or other events, to prevent damage to equipment and disruption of service. Also called surge arresters.

Classification of Substation

There can be two types of substations:
1] Based on service requirement
2] Based of constructional feature

1] Based on service requirement:
A substation may be called upon to change voltage level or improve power factor or convert AC power to DC power. According to service requirement substation may be classified as:
1] Transformer Substation
2] Switching Substation
3] Power Factor Correction Substation
4] Frequency Changer Substation
5] Converting Substation
6] Industrial Substation

Transformer Substation:

Those substation which changes the voltage levels are called transformer substation. Transformer will be the main component of these substation.

Switching Substation:

It keeps voltage level same that is incoming and outgoing lines have same voltage level. It only performance switching operation of power lines for maintenance or to use stand by line at the time of breakdown.

Power Factor Correction Substation:

It dose Power Factor Correction. Such substations are located at receiving end of transmission lines and power factor can be improved by using synchronous condenser.

Frequency Changer Substation:

It changes frequency of supply. Such substation are required for industrial utilization.

Converting Substation:

It converts AC power to DC power with suitable apparatus, for transmission along the long distances, for traction, for electroplating, for electric welding, for DC motors etc.

Industrial Substation:

It supplies power to individual industrial concern.

2] Based of constructional feature:

Substation has many component for example circuit breaker, switches, etc which must be based properly to insure continuous & reliable service. According to the constructional feature substations are classified as:

1] Indoor Substation

2] Outdoor Substation

3] Underground Substation

4] Pole Mounted Substation

Indoor Substation





Indoor Substations is installed within the substation building. Such substations are usually for the rating of 22 kV below because of economic consideration . Indoor Substations are preferred in heavily polluted areas and Power Substations situated near the seas (saline atmosphere causes Insulator Failures results in Flashovers)

Outdoor Substation

The necessary clearances b/w conductors and the space required for switches, circuit breakers, transformers, and other equipment become so great for voltages above 22 000 volts that it is generally more economical to install all such equipment outdoors.

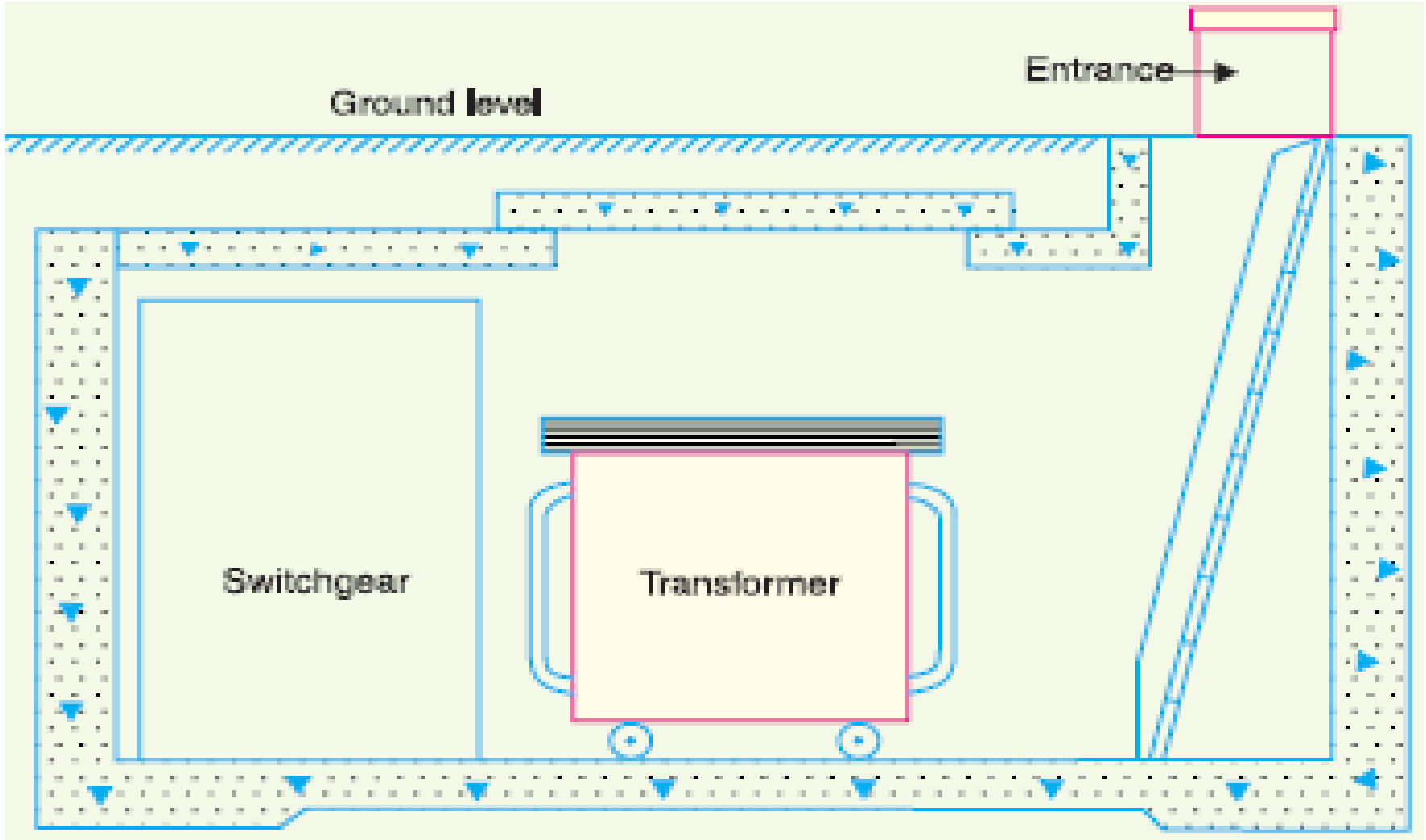
https://www.youtube.com/watch?v=ejC7bTBQo24

Underground Substation

In thickly populated areas the space available foe the equipment & building is limited and cost of land is high. In this situation the substation is developed underground and equipment are placed underground. While laying out such substation some points are to be kept in view:

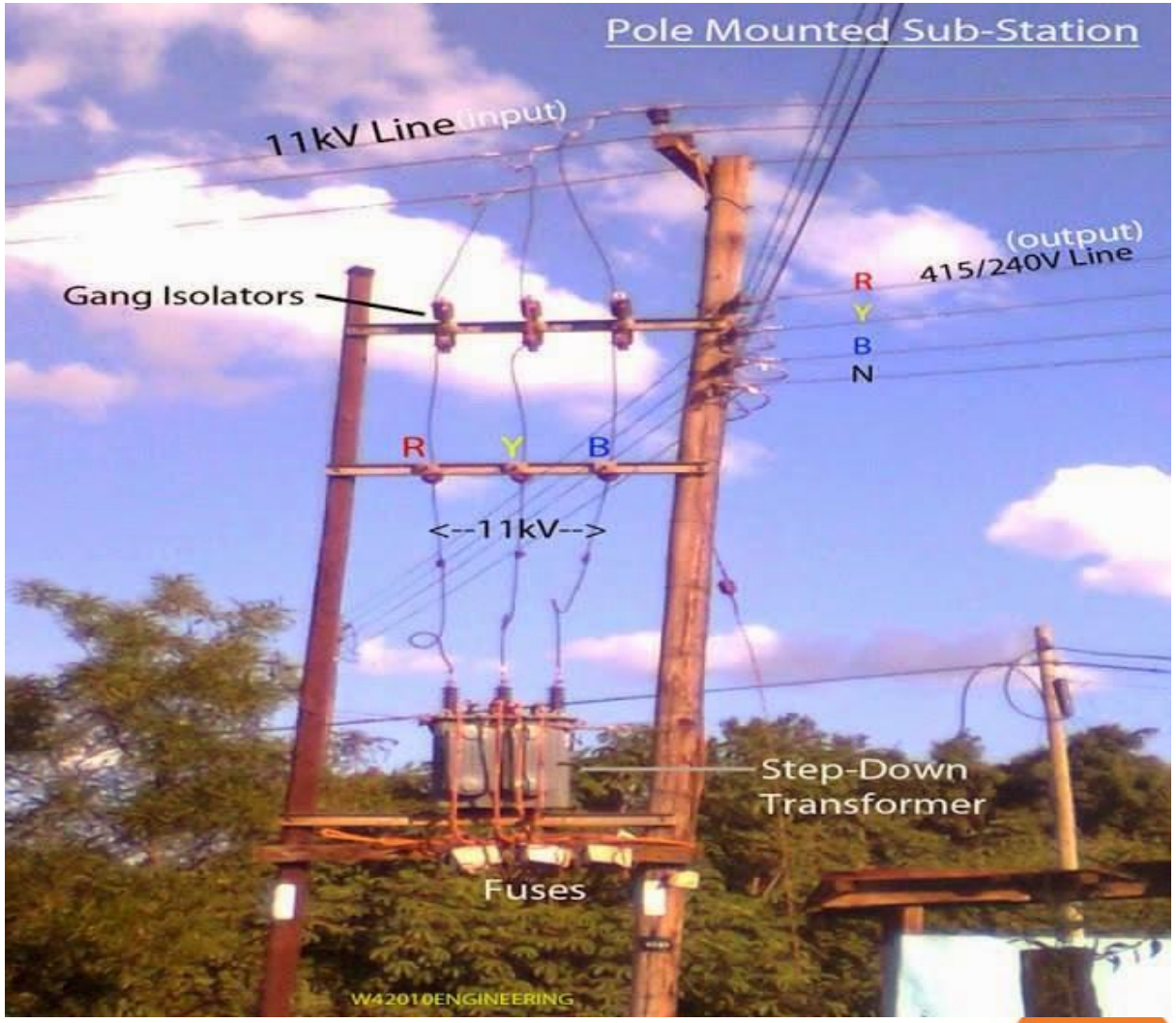
1. The size of station should be as minimum as possible.
2. There should be provision for protection against fire.
3. There should be good ventilation.
4. There should be provision for remote indication of excessive rise in temperature so that supply can be disconnected.
5. The transformer, switches etc. should be air cooled to avoid bringing oil into the premises.

Underground Substation



Pole Mounted Substation

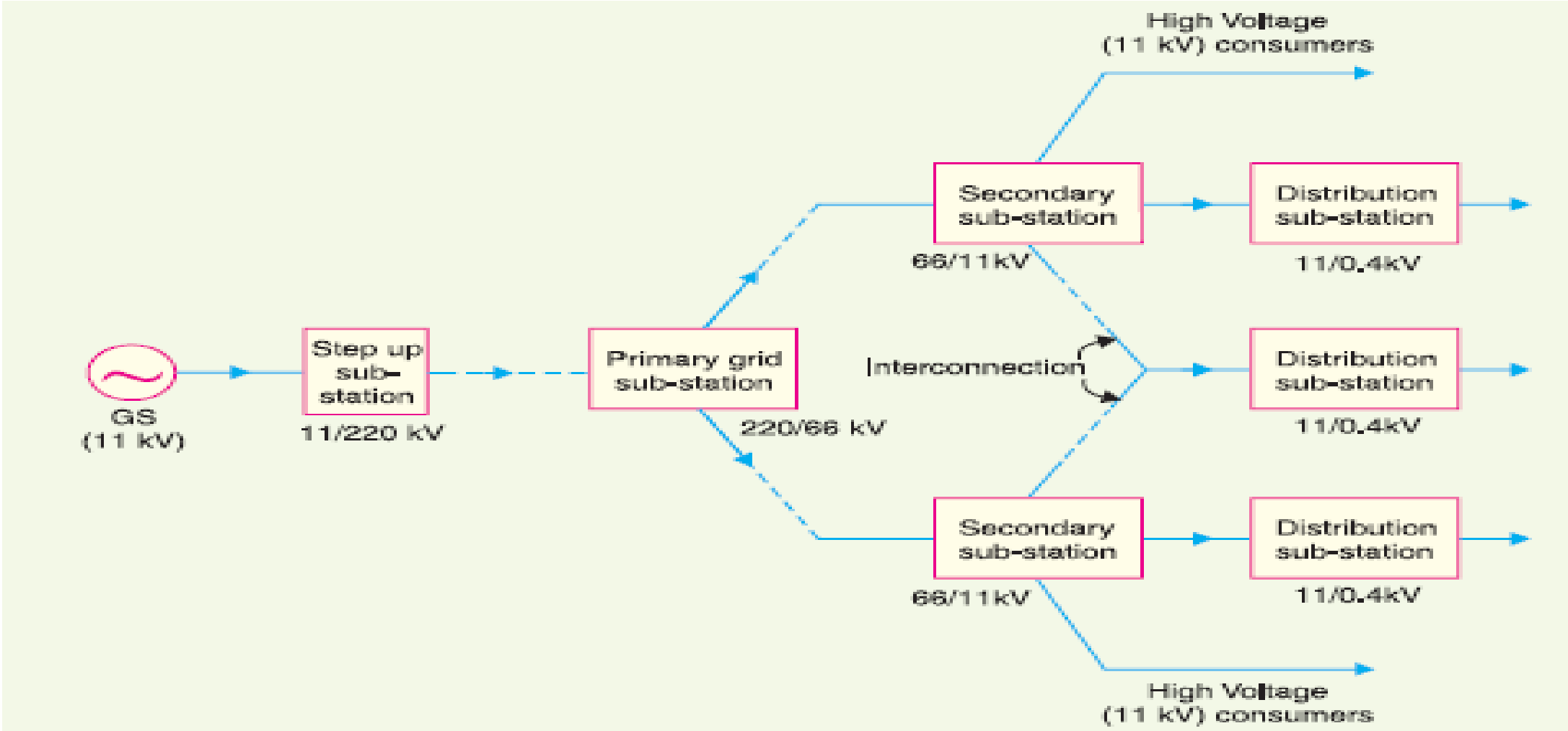
This is an outdoor substation with equipment installed overhead on H pole or 4 pole structure. It is the cheapest form substation as it does not involve any building work and used for the voltages not exceeding 11kV or 33kV. Electric power is distributed in localities through such substation hence called distribution substation.



Comparison of Outdoor and Indoor Substation

Outdoor	Indoor
1.More space required	1.Less space required
2.Less time required for erection	2.More time required for erection
3.Easy future extension	3.Difficult future extension
4.Easier fault location because of equipment being in full view.	4.Difficult fault location because of equipment not being in full view.
5.Low capital cost	5.High capital cost
6.Difficult operation	6.Easier operation
7.Possibility of fault escalation is less.	7.Possibility of fault escalation is more.

Transformer Substation



Majority of substations in the power system are concerned with changing of voltage level of electric supply. These are known as transformer substation because transformer is the main component used to change voltage level. Depending upon the purpose transformer substation are classified into:

1] Step up Substation: Generating voltage is stepped up to high voltage. These are generally located in power houses and of outdoor type.

2] Primary grid Substation: Power from 3phase 3wire transmission line is received and stepped down to low voltage level for secondary transmission.

3] Secondary Substation: Here voltage is again stepped down and these are located at the strategic points in the city.

4] Distribution Substation: These are located near the consumer locality and stepped down the voltage to 400V, 3ph, 4wire for supplying to the consumer. These are of pole mounted type.

Comparison of D.C. and A.C. Transmission

D.C. transmission : For some years past, the transmission of electric power by d.c. has been receiving the active consideration of engineers due to its numerous advantages.

Advantages :

(i) It requires only two conductors as compared to three for a.c. transmission

(ii) There is no inductance, capacitance, hence no surge problems in d.c. transmission.

(iii) Due to the absence of inductance, the voltage drop in a d.c. transmission line is less than the a.c. line for the same load and sending end voltage. For this reason, a d.c. transmission line has better voltage regulation.

(iv) There is no skin effect in a d.c. system. Therefore, entire cross-section of the line conductor is utilized.

(vii) In d.c. transmission, there are no stability problems and synchronizing difficulties, that's why easily synchronized.

Disadvantages :

(i) Electric power cannot be generated at high d.c. voltage due to commutation problems.
(ii) The d.c. voltage cannot be stepped up for transmission of power at high voltages
(iii) The design of d.c. switches and circuit breakers is complicated and expensive.

A.C. transmission: Now-a-days, electrical energy is almost exclusively generated, transmitted and distributed in the form of a.c.

Advantages :

(i) The power can be generated at high voltages.
(ii) The maintenance of a.c. sub-stations is easy and cheaper.
(iii) The a.c. voltage can be stepped up or stepped down by transformers with ease and efficiency. This permits to transmit power at high voltages and distribute it at safe potentials.

Disadvantages :

(i) An a.c. line requires more copper than a d.c. line since three conductors are required.

(ii) The construction and installation of a.c. transmission line is more complicated than a d.c. transmission line.

(iii) Due to skin effect in the a.c. system, the effective resistance of the line is increased.

(iv) An a.c. line has capacitance. Therefore, there is a continuous loss of power due to charging current even when the line is on no load.

(v) If the level of transmission voltage is increased, the cost of transformer, switchgear, Las, insulation also increases.

Load Characteristic



Importance of Load Curve:

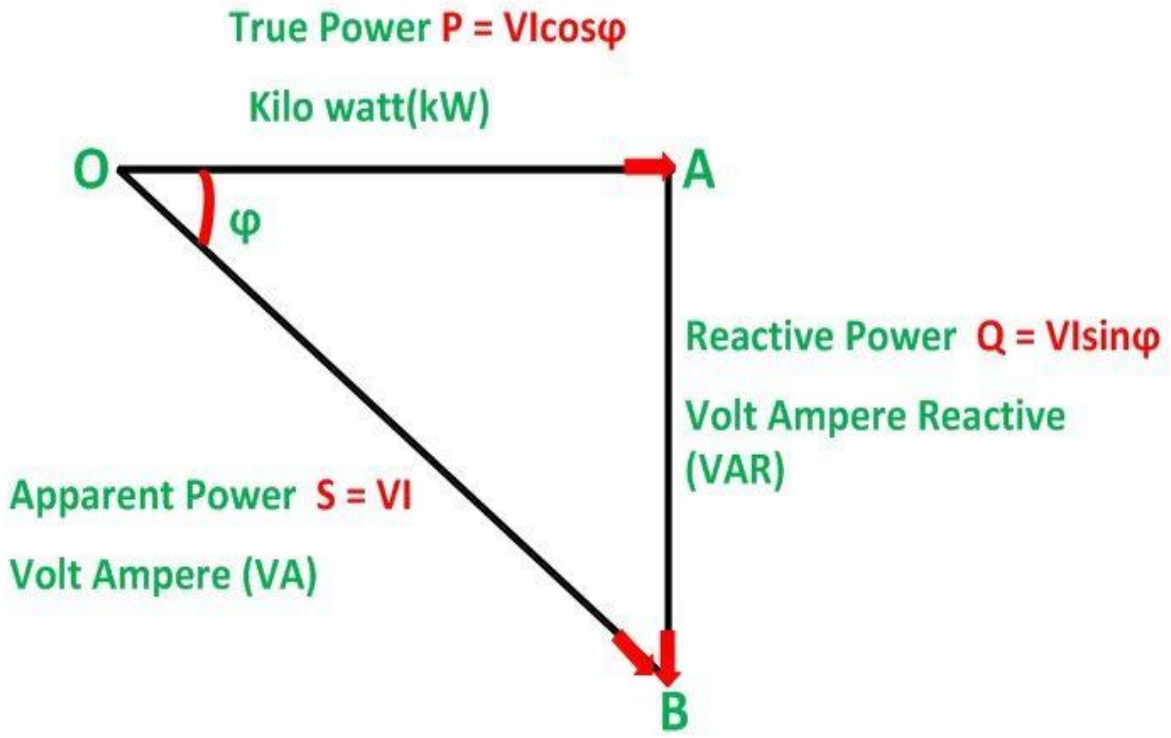
- The Daily Load Curve gives the information of load on the power station during different running hours of the day.
- The number of unit's generation per day is found from the area under the daily Load Curve.
- Average load is found from the Load Curve.
- **Average load= [Area (KWh) under daily load curve/24 hours]**
- The maximum demand of the station on that day is found from the highest point of the daily Load Curve.
- The size and the number of generating units can be determined from the load curve.
- This Load Curve helps to determine the operation schedule of the station. In that case when all the units or the less units needs to running is found.

Complex Power

- The portion of power that, averaged over a complete cycle of the AC Waveform, results in net transfer of energy in one direction is known as ***active power***, more commonly called ***real power (P)***

- The portion of power due to stored energy, which returns to the source in each cycle, is known as ***reactive power (Q)***

- The combination of active power and reactive power gives ***Complex Power (S)***



Engineering | Management | Law | Schools | Other Courses
NAGPUR PUNE JALGAON AMRAVATI AHMEDNAGAR CHHINDWARA
RAISONI GROUP OF INSTITUTIONS

$$\bar{S} = \bar{V}_{rms}\bar{I}^{*}_{rms} = \frac{1}{2}\bar{V}\,\bar{I}^{*}$$

$\bar{S}$=P+jQ

S	complex	KVA	Apparent Power
P	real	KW	Real Power
jQ	imaginary	KVAR	Reactive Power

$$\bar{S} = \bar{V}_{rms}\bar{I}^{*}_{rms}$$

$$\bar{S} = V_{rms}\angle\theta_V \left(I_{rms}\angle\theta_I\right)^{*}$$

$$\bar{S} = \left(V_{rms}\ I_{rms}\right)\angle\left(\theta_V - \theta_I\right)$$

$$\bar{S} = \left(V_{rms}\ I_{rms}\right)\cos\left(\theta_V - \theta_I\right) + j\left(V_{rms}\ I_{rms}\right)\sin\left(\theta_V - \theta_I\right)$$

$$\bar{S} = P + jQ$$

Voltage Dependence of Load

$$\frac{\partial P}{P} = 2\,\frac{\partial V}{V}$$

Change in Power = 2* Change in Voltage

Frequency Dependence of Load

$$\frac{\delta P}{P} = -0.72 \frac{\delta f}{f}$$

Change in Power = - 0.72* Change in Frequency

Advantages of High Transmission Voltages

1] Reduces Volume of conductor material and power loss

2] Increases transmission efficiency

3] Decreases percentage line drop

Thank you !